PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

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NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

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Crystal Plaza 2
Washington, DC 20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 06 March 1998 (06.03.98)	
International application No. PCT/IB97/00903	**Applicant's or agent's file reference** 299.004W01
International filing date (day/month/year) 18 July 1997 (18.07.97)	**Priority date** (day/month/year) 19 July 1996 (19.07.96)
Applicant SEGAL, Mordechai et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

18 February 1998 (18.02.98)

[ ] in a notice effecting later election filed with the International Bureau on:

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[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

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NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

PEARL, Zeev
Eitan, Pearl, Latzer & Cohen-Zedek
Lumir House
Maskit Street 22
46733 Herzelia
ISRAËL

Date of mailing (day/month/year)
06 March 1998 (06.03.98)

Applicant's or agent's file reference
299.004W01

IMPORTANT NOTIFICATION

International application No.
PCT/IB97/00903

International filing date (day/month/year)
18 July 1997 (18.07.97)

1. The following indications appeared on record concerning:

[ ] the applicant [ ] the inventor [X] the agent [ ] the common representative

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Facsimile No.

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2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [ ] the name [X] the address [ ] the nationality [ ] the residence

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3. Further observations, if necessary:

4. A copy of this notification has been sent to:

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[X] the International Preliminary Examining Authority
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[ ] other:

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COMMUNICATION OF
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(PCT Article 20)

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Date of mailing:
26 February 1998 (26.02.98)

The International Bureau transmits herewith copies of the international applications having the following international application numbers and international publication numbers:

International application no.:	International publication no.:
PCT/IB97/00903	WO98/04073

CORRECTED VERSION
VERSION CORRIGEE

The International Bureau of WIPO
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PATENT COOPERATION TREATY

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INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
299.004W01		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/IB 97/00903	18/07/1997	19/07/1996
Applicant		
LIBIT SIGNAL PROCESSING LIMITED et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 6 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. ☐ **Certain claims were found unsearchable** (see Box I).

2. ☒ **Unity of invention is lacking** (see Box II).

3. ☐ The international application contains disclosure of a **nucleotide and/or amino acid sequence listing** and the international search was carried out on the basis of the sequence listing
   - ☐ filed with the international application.
   - ☐ furnished by the applicant separately from the international application,
     - ☐ but not accompanied by a statement to the effect that it did not include matter going beyond the disclosure in the international application as filed.
   - ☐ Transcribed by this Authority

4. With regard to the **title,**
   - ☐ the text is approved as submitted by the applicant.
   - ☒ the text has been established by this Authority to read as follows:

   BLIND DFE AND PHASE CORRECTION

5. With regard to the **abstract,**
   - ☐ the text is approved as submitted by the applicant.
   - ☒ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this International Search Report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is:

   Figure No. 3
   - ☒ as suggested by the applicant.
   - ☐ because the applicant failed to suggest a figure.
   - ☐ because this figure better characterizes the invention.
   - ☐ None of the figures.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 97/00903

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see continuation sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1,2,20

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

1. claims 1,2,20: equalisation with a pre-equaliser to reduce eigenvalue spread
2. claim 3: blind equalisation
3. claim 4: blind compensation for phase offsets
4. claim 5: blind decision feedback equalisation
5. claim 6: equalisation with an FIR filter as a pre-equaliser
6. claims 7-13: adaptation rules
7. claim 14: decision feedback equaliser with compensation for phase offsets
8. claim 15: receiver for various modulation formats
9. claims 16-19: decision feedback equalisation with a pre-equaliser, phase rotator
10. claim 21: equalisation in a digital subscriber loop of a telephone network
11. claim 22: equalisation in a coaxial cable television network

Box III TEXT OF THE ABSTRACT (Continuation of item 5 of the first sheet)

The digital communications receiver receives an analogue signal, modulated with digital information. The receiver converts the analogue signal to a digital signal, and demodulates the digital signal to recover the complex valued components of the transmitted digital signal. The complex valued components are low pass filtered and passed through an adaptive pre-equaliser filter, to reduce eigenvalue spread. The filtered complex valued signal is then subject to decision feedback equalisation, which operates using a series of adaptive filters additionally to remove artifacts of inter-symbol interference. The resulting filtered and equalised complex valued signal is then converted to a digital signal to recover the digital information.

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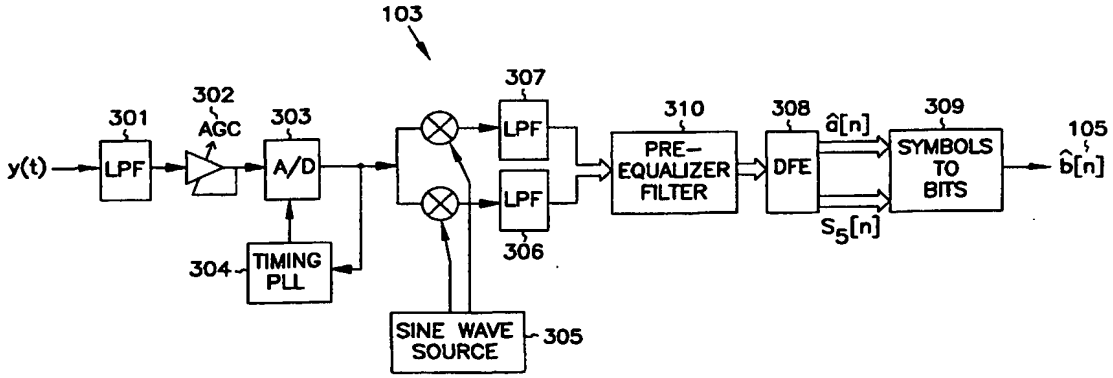

(57) Abstract

The digital communications receiver receives an analog signal, modulated with digital information. The receiver converts the analogue signal to a digital signal, and demodulates the digital signal to recover the complex valued components of the transmitted digital signal. The complex valued components are low pass filtered and passed through an adaptive pre-equalizer filter, to reduce eigen value spread. The filtered complex valued signal is then subject to a decision feedback equalisation, which operates using a series of adaptive filters additionally to remove artifacts of inter-symbol interference. The resulting filtered and equalized complex valued signal is the converted to a digital signal to recover the digital information.

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BLIND DFE AND PHASE CORRECTION

FIELD OF THE INVENTION

The present invention relates to digital communication methods and systems.

BACKGROUND OF THE INVENTION

Modems for digital communications systems are designed to cope with various channel impairments. An essential element of the modem is the start-up process in which modem parameters such as equalizer taps, carrier frequency error, timing error, and gain setting, are estimated in order to provide the required modem performance.

In the prior art, two training modes are used: 1) using a known transmitted data sequence; 2) or using the transmitted information data without any prior knowledge of the value of the transmitted data. The latter mode is known as a blind start-up.

In the prior art, it is difficult to perform a blind start-up process, with limited computational resources and to converge to a good initial setting of the modem parameters for channels that exhibit severe linear distortion which gives rise to severe inter-symbol interference (ISI), and channels that suffer from severe narrow-band interference.

Therefore, there is a need in the art to provide a solution for the blind start-up process of a receiver in the context of digital communications signals in the presence of severe ISI and severe narrow-band interference. There is an additional need in the art to provide relief from ISI and severe narrow-band interference for conventional blind and non-blind modems.

SUMMARY OF THE INVENTION

The present invention is a method and apparatus for a digital communication receiver which is capable of operating over channels with severe ISI and narrow-band interference in either blind or non-blind modems.

The receiver of the present invention receives an analog signal modulated with digital information. The receiver converts the analog signal to a digital signal and demodulates the digital signal to recover the complex valued

components of the transmitted digital signal. The complex valued components are low pass filtered and passed through an adaptive pre-equalizer filter to reduce eigen value spread correlation.. The filtered complex valued signal is then subjected to a decision feedback equalizer which operates using a series of adaptive filters to additionally remove artifacts of inter-symbol interference. The resulting filtered and equalized complex valued signal is the converted to a digital signal to recover the digital information.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 depicts a digital communications system which employs the invention in a preferred embodiment.

Figure 2 describes the transmitter in the preferred embodiment of Figure 1.

Figure 3 describes the structure of the receiver in the preferred embodiment.

Figure 4 describes the operation of the pre-equalizer filter unit of the receiver in the preferred embodiment.

Figure 5 describes operation of the DFE (Decision Feedback Equalizer) in the receiver of the preferred embodiment.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In the following detailed description of the preferred embodiments, reference is made to the accompanying drawings which form a part hereof, and in which is shown by way of illustration specific preferred embodiments in which the inventions may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that structural, logical and electrical changes may be made without departing from the scope of the present inventions. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present inventions is defined only by the appended claims.

Reference is made to Figure 1 which illustrates a typical application of a digital communications system operating over UTP (Unshielded

Twisted Pair) copper cables plant 102 or another communication medium such as coaxial cable. The present invention is applicable to many types of communication mediums, and in particular to a digital subscriber loop of a telephone network or a coaxial cable television infrastructure. The system comprises a transmitter 101 that receives a sequence 104 of data bits b[n], and outputs a signal x(t) to the cable. A wired communications medium 102, such as a copper cable plant, connects the transmitter 101 to the blind receiver 103. The blind receiver 103 receives a signal y(t) from the communications medium 102 and outputs a sequence of detected digital data bits $\hat{b}[n]$ 105.

The communications medium or cable plant may have one or more unterminated wire drops 106, as illustrated in Figure 1, and these wire drops may cause severe reflections that distort the signal and introduce significant inter-symbol interference (ISI).

Reference is made now to Figure 2, which describes the structure of the transmitter 101. In figure 2, the single-lined arrows indicate the propagation of real valued signals and the double-lined arrows indicate the propagation of complex valued signals. Real valued signals are a subset of complex valued signals and thus whenever the term "complex valued" is used herein, it encompassed either imaginary or real valued signals or the combination of the two which is a complex valued signals. The transmitter 101 operates according to a general approach of linear transmission that particularly include any one of PAM (Pulse Amplitude Modulation), QAM (Quadature Amplitude Modulation), PSK (Phase Shift Keying), CAP (Carrierless AM-PM), and NRZ (Non-Return to Zero) transmission methods, among others. The input data bits sequence b[n] is converted to a sequence of I-Q complex valued symbols, a[n], by a bit-to-symbol conversion unit 201, that may comprise a scrambler, a differential encoder, a trellis or a block FEC (Forward Error Correction) encoder, a CRC error protection encoder, a framer, a shell mapper, and/or protocol layer units.

The sequence a[n] is then fed to a cascade of transmission filter 202, an up-converter 203, where it is multiplied by sine and cosine sequences

that are generated in the sine wave source 204, a Digital to Analog (D/A) converter 205, an analog LPF (Low Pass Filter) 206 whose cutoff frequency is designed to reject aliasing effects of the D/A, and an amplifier 207. The output of the transmitter is the analog signal x(t).

Reference is now made to Figure 3 which illustrates the structure of the blind receiver 103. The input to the blind receiver is an analog signal y(t) that has propagated through the wired communications medium 102, such as a copper cable plant. This signal may suffer from severe reflections and linear distortions and it may contain a high level of noise and interference components due to e.g. narrow-band radio transmissions which occupy the same frequency band of the signal y(t).

The receiver input signal is low-pass filtered by the LPF 301 which is designed to combat sampling aliasing effects, then it is amplified by an amplifier 302 whose gain is automatically adjusted with an Automatic Gain Control (AGC) to exploit the dynamic range of sampler, and then the signal is sampled by Analog to Digital converter (A/D) 303. The sampling phase of the A/D is adaptively controlled by a timing PLL (phase locked loop) 304, which adjusts the sampling phase so that the power of the A/D output is maximized. Those skilled in the art will readily recognize that the timing PLL 304 may alternatively employ other conventional timing methods, such as decision directed timing.

The A/D output sequence is then down-converted by multiplying it with sine and cosine sequences that are synthesized in a sine wave source 305, and the resulting I and Q components are low pass filtered by the LPFs 306 and 307. Both LPFs 306 and 307 are designed to remove the demodulation image, to remove out-of-band signals, and to match the response frequency of the cascade of the transmission pulse response of transmit filter 202 of a typical cable plant or other communication medium 102 upon which the system operates.

The LPF units' outputs are then processed by a pre-equalizer filter unit 310, whose operation is described below in conjunction with Figure 4, and a Decision Feedback Equalizer (DFE) unit 308, whose operation is described

below in conjunction with Figure 5. The output of the DFE unit 308 is a sequence of detected I-Q symbols â[n] and an equalized sequence $s_5[n]$. These sequences are then processed by a symbol-to-bits conversion unit 309 that performs the inverse function of the bits-to-symbols conversion unit 201 and may employ a descrambler, differential decoder, FEC decoders, deframer, shell demapper, and/or a protocol layer decoder. The output of this unit is a sequence of the detected data bits $\hat{b}[n]$ 105.

Figure 4 illustrates the pre-equalizer filter unit 310. The input sequence of the unit, $s_1[n]$ is filtered by a digital FIR (Finite Impulse Response) filter 401 with L taps $p_n[1]...p_n[L]$ ($L \geq 0$) where $p_n[l]$ denotes the l-th tap after n iterations. The taps of the filter are adaptively adjusted by an adaptation unit 402. The adaptation rule is:

$$p_{n+1}[l] = p_n[l] + \Gamma_n(s_2[n])s_1^*[n-l] \qquad l = 1 \ldots L$$

where $s_2[n]$ is the output of the FIR filter 401, and where $\Gamma_n(x)$ is a possibly nonlinear function 403 whose parameters may vary with the iteration index n. A recommended class of Γ function is:

$$\Gamma_n(x) = \delta_p[n] \bullet x$$

where $\delta_p[n]$ $n = 1,2,...$ is a sequence of step sizes. The signal undergoes the following transformation:

$$s_2[n] = s_1[n] + \sum_{l=1}^{L} p_n[l]s_1[n-l] \quad (L \geq 0)$$

The input signal for the pre-equalization filter unit 310 is denoted $s_1[n]$ in Figure 4 and is routed to the FIR filter 401, the adaptation unit 402 and to summation circuit 404. $s_1[n]$ is combined with the output of the adaptive FIR filter 401 to produce the output signal $s_2[n]$ of the pre-equalization filter unit 310. The non-linear circuit 403 modifies the $s_2[n]$ signal to provide the feedback to adjusting the taps if adaptive FIR filter 401.

Figure 5 illustrates the DFE (Decision Feedback Equalizer). The DFE's input sequence $s_2[n]$ is first rotated by an adaptive rotator 501, by an

angle $\theta[n]$. The rotated sequence is then filtered by an FFE (Feed Forward Equalizer) FIR filter 502 whose taps' values are $c_n[1]..c_n[M]$ ($M \geq 1$), to produce output signal $s_3[n]$. Signal $s_3[n]$ is then summed 507 with the output of an adaptive FIR filter 504 whose taps are $d_n[1]..d_n[N]$, $N \geq 0$, and which is driven by the sequence of detected symbols â[n]. The result of this summation is equalized sequence $s_5[n]$, 506. The sequence 506 is fed to a symbol detector 503 that employs a memoryless nearest neighbor decision rule, based on the transmitted symbols' I-Q constellation to generate the sequence â[n]. We note that in this preferred embodiment, a single memoryless decision rule is employed. However, the present invention can be employed in a receiver that employs a more accurate detection scheme such as an approximate nearest sequence detector which is the maximum likelihood sequence estimator when the noise of the input of unit 503 has a Gaussian distribution.

The parameters of units 501, 502 and 504 are jointly updated by $S_5[n]$ to combat ISI (Inter-Symbol Interference) and noise. The adaptation scheme is the following:

$$\theta[n+1] = \theta[n] + \rho_n(s_5[n])$$
$$c_{n+1}[m] = c_n[m] + \varphi_n(s_5[n])s_3^*[n-m] \qquad m = 1...M$$
$$d_{n+1}[i] = d_n[i] + \Psi_n(s_5[n])\hat{a}^*[n-i] \quad i = 1...N$$

where $\rho_n(x)$, $\varphi_n(x)$, and $\Psi_n(x)$ are possibly nonlinear complex valued scalar function whose parameters may depend on the iteration index n, and $M \geq 1$, $N \geq 0$.

The adaptation functions in this embodiment are:

$$\varphi_n(x) = \begin{cases} \delta_c[n](x - \hat{a}(x)) & n > T_2^c \\ \delta_c[n]\left(|x|^2 - k_1\right)x & T_1^c \le n < T_2^c \\ \delta_c[n]\left(\mathrm{Re}^2(x) - k_2\right)\mathrm{Re}(x) & n < T_1^c \end{cases}$$

$$\rho_n(x) = \begin{cases} \delta_\theta[n]\left(\mathrm{Re}^2(x) - k_2\right)\mathrm{Re}(x)\,\mathrm{Im}(x) & n < T_1^\theta \\ \delta_\theta[n]\,\mathrm{Im}\left(\hat{a}(x)x^*\right) & n \ge T_1^\theta \end{cases}$$

$$\Psi_n(x) = \begin{cases} \delta_d[n](x - \hat{a}(x)) & n > T_2^d \\ \delta_d[n]\left(|x|^2 - k_1\right)x & T_1^d \le n < T_2^d \\ \delta_d[n]\left(\mathrm{Re}^2(x) - k_2\right)\mathrm{Re}(x) & n < T_1^d \end{cases}$$

where $\delta_c[n]$, $\delta_d[n]$ and $\delta_\theta[n]$, $n = 1, 2, \ldots$, are sequences of real-valued step sizes, where k_1 and k_2 are real valued scalars, and where Re(-) and Im(-) denote the real part and the imaginary part of a complex scalar, and where $\hat{a}(x)$ is the result of a memoryless nearest neighbor symbol detector whose input is x. T_1^c, T_2^c, T_1^θ, T_1^d and T_2^d are positive scalars.

The sequences $s_1[n]...s_5[n]$, â[n] may be calculated at the symbols rate (T-spaced receiver). Alternatively $s_2[n]$, $s_3[n]$ and $s_4[n]$ may be calculated at a higher rate (Fractionally spaced receiver). The resulting outputs of units 501, 502 and 504 are described as follows:

$$s_3[n] = s_2[n] \bullet e^{j\theta[n]}$$

$$s_4[n] = \sum_{m=1}^{M} c_n[m] s_3[n-m]$$

$$s_5[n] = s_4[n] + \sum_{I=1}^{N} d_n[i] \hat{a}[n-I]$$

CONCLUSION

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement which is calculated to achieve the same purpose may be substituted for the specific embodiments shown. This patent is intended to cover any adaptations or variations of the present invention. Therefore, it is manifestly intended that this invention be limited only by the claims and the equivalents thereof.

We Claim:

1. A communication receiver, comprising:

an input receiving a modulated analog signal containing digital information;

a front end unit operable for performing analog to digital conversion, for performing demodulation and for performing timing control, and further operable for producing a demodulated complex-valued digital signal from the modulated analog signal;

a digital equalizer connected for receiving the demodulated complex valued digital signal, comprising:

a first filter operable receiving the demodulated complex valued digital signal;

a second filter connected to the first filter and operable for reducing the amount of noise and inter symbol interference in the demodulated complex valued digital signal; and

a symbol-to bit converter connected to the second filter.

2. The communication receiver according to claim 1 wherein the first filter operates to reduce the eigenvalue spread of an input spectrum of the demodulated complex valued digital signal.

3. The communication receiver according to claim 1 wherein the second filter is further operable for reducing the amount of noise and inter symbol interference of the demodulated complex valued digital signal without training data.

4. The communication receiver according to claim 1 wherein the second filter further includes a rotator for restoring the phase of the demodulated complex valued digital signal without the use of training data.

5. The communication receiver according to claim 1 wherein the second filter further includes a nonlinear feedback network for removing the inter-symbol interference without the use of training data in the demodulated complex valued digital signal.

6. The communication receiver according to claim 1 wherein the first filter further comprises an L-tap Finite-Impulse-Response (FIR) Filter, where $L \geq 1$, whose first tap is set to a fixed value, and the filter's taps are adjusted so that its output power is minimized.

7. The communication receiver according to claim 1 wherein the second filter further comprises an M-tap FIR filter whose taps are adjusted according to the following formula:

$$c_{n+1}[m] = c_n[m] + \varphi_n\left(s_5[n]\right) s_3^*[n-m] \qquad m = 1...M$$

where $c_n[m]$ is the m-th tap of the second filter after calculation of n outputs, $s_3[n]$ is the input sequence to the second filter, $s_5[n]$ is the sum of the output of the second filter and a decision feedback filter, and $\varphi_n(\bullet)$ is a complex valued function, whose parameters may depend on the symbol index n.

and the decision feedback filter is an N-tap backward FIR filter whose taps are adjusted according to the following formula:

$$d_{n+1}[i] = d_n[i] + \Psi_n(s_5[n])\,\hat{a}^*[n-i] \qquad i = 1...N$$

where $d_n[i]$ is the I-th tap of the decision feedback filter after calculation of n outputs, $\hat{a}[n]$ is a sequence of detected data, and $\Psi_n(\bullet)$ is a complex valued function, whose parameters may depend on the symbol index n.

8. The communication receiver according to claim 7, wherein for some values of n:

$$\varphi_n(x) = \delta[n]\left(\mathrm{Re}^2(x) - k_2\right)\mathrm{Re}(x)$$

where Re(-) denotes the real part of a complex number, k_2 is a scalar, and $\delta[n]$ n = 1, 2, ... is a sequence of numbers.

9. The communication receiver according to claim 7, where for some values of n:

$$\varphi_n(x) = \delta[n]\left(|x|^2 - k\right)(x)$$

where k is a scalar, and $\delta[n]$ is a sequence of numbers.

10. The communication receiver according to claim 7, where some values of n:

$$\varphi_n(x) = \delta[n]\left(x - \hat{a}(x)\right)$$

where $\hat{a}(x)$ is the result of a memoryless nearest neighbor symbol detector whose input is x, and $\delta[n]$ is a sequence of numbers.

11. The communication receiver according to claim 7, where some values of n:

$$\Psi_n(x) = \delta[n]\left(\mathrm{Re}^2(x) - k\right)\mathrm{Re}(x)$$

where k is a scalar, and $\delta[n] = 1, 2, \ldots$ is a sequence of numbers.

12. The communication receiver according to claim 7, where for some values of n:

$$\Psi_n(x) = \delta[n]\left(|x|^2 - k\right)(x)$$

where k is a scalar, and $\delta[n]$ is a sequence of numbers.

13. The communication receiver according to claim 7, where some values of n:

$$\Psi_n(x) = \delta[n]\left(x - \hat{a}(x)\right)$$

where $\hat{a}(x)$ is the result of a memoryless nearest neighbor symbol detector whose input is x, and $\delta[n]$ is a sequence of numbers.

14. The communication receiver according to claim 1, wherein the second filter further comprises:

an adaptive rotator connected to receive the demodulated complex valued digital signal;

an adaptive feed forward equalizer finite impulse response filter connected to the adaptive rotator;

a signal summation circuit connected to the adaptive feed forward equalizer finite impulse response filter and to an adaptive finite impulse response filter, the output of which is connected to update the adaptive rotator, the an adaptive feed forward equalizer finite impulse response filter and the adaptive finite impulse response filter;

a symbol detector connected to the signal summation circuit and the symbol-to-bit convertor; and

the adaptive finite impulse response filter connected to the symbol detector and operable for adapting to the summation result of the signal summation circuit.

15. The communication receiver according to claim 1, wherein the modulated analog signal is a modulation type selected from the group consisting of PAM (Pulse Amplitude Modulation), QAM (Quadature Amplitude Modulation), PSK (Phase Shift Keying), CAP (Carrierless AM-PM) , NRZ (Non-Return to Zero), offset-QPSK, and $\pi/4$-QPSK.

16. A digital communication receiver, comprising:

a input stage receiving an analog signal containing digital information;

an analog to digital converter connected for producing a complex-valued digital signal from the modulated analog signal;

a demodulator connected for producing a demodulated complex-valued digital signal from the complex-valued digital signal;

a pre-equalizer filter connected to receive the demodulated complex-valued digital signal, comprising:

a first adaptive finite response filter having an output, having a tap adjustment input and connected to receive the demodulated complex-valued digital signal;

a first summation circuit connected to sum the demodulated complex-valued digital signal with the output of the first adaptive finite response filter to produce a pre-equalized complex-valued signal;

a function circuit connected to receive the pre-equalized complex-valued signal and operable for producing therefrom a non-linear response to the pre-equalized complex-valued signal;

an adaptation unit connected to receive the demodulated complex-valued digital signal, connected for receiving the non-linear response and connected to the tap adjustment input of the adaptive finite response filter to provide an adjustment to the first adaptive finite response filter;

a digital decision feedback equalizer connected to receive the pre-equalized complex-valued signal, comprising:

a rotator having an adaptive input and connected to receive the pre-equalized complex-valued signal and operable for restoring the phase

of input data contained in the pre-equalized complex-valued signal without the use of training data;

a feed forward equalizer finite input response filter having an adaptive input, an input connected to the rotator, an output, and operable for adaptively reducing the amount of noise and inter-symbol interference in the pre-equalized complex-valued signal;

a second summation circuit connected to sum the output of the feed forward equalizer finite input response filter with the output of a second adaptive finite response filter and for producing therefrom a corrected complex-valued signal;

a symbol detector connected to receive the corrected complex valued signal and to produce a symbol signal;

the second adaptive finite response filter having an output, an adaptive input and connected to receive the symbol signal;

wherein the corrected complex-valued signal is connected to the adaptive input of the rotator, the adaptive input of the feed forward equalizer finite input response filter and the adaptive input of the second adaptive finite response filter; and

a symbol-to-bit converter connected to receive the symbol signal and to produce therefrom digital bits corresponding to the digital information.

17. A method of receiving a digital communication signal in the presence of inter-symbol interference, comprising the steps of:

receiving an analog signal modulated with digital information;

converting the analog signal to produce a digital signal;

multiplying the digital signal with sine and cosine signals to produce a complex-valued digital signal;

adaptively pre-equalizing the complex-valued digital signal to produce a pre-equalized complex-valued digital signal;

adaptively equalizing the pre-equalized complex-valued signal to reduce the inter-symbol interference and to produce a corrected complex valued symbol signal; and

converting the corrected complex valued symbol signal to the digital information.

18. The method according to claim 17, wherein the step of adaptively pre-equalizing further comprises the steps of:

adaptively filtering the complex-valued digital signal with an adaptive filter to produce a filtered complex-valued digital signal

summing the complex-valued digital signal with the filtered complex-valued digital signal to produce the pre-equalized complex-valued digital signal;

producing a non-linear response to the pre-equalized complex-valued signal; and

modifying taps of the adaptive filter in response to the non-linear response to the pre-equalized complex-valued signal and in response to the complex-valued digital signal.

19. The method according to claim 17, wherein the step of adaptively equalizing further comprises the steps of:

adaptively rotating the pre-equalized complex-valued signal to produce a rotated complex valued signal;

adaptively filtering the rotated complex valued signal to produce a filtered rotated complex valued signal;

summing the filtered rotated complex valued signal with an adapted filter output to produce an adapted complex-valued signal;

detecting the symbols in the adapted complex-valued signal to produce the corrected complex valued symbol signal; and

producing the adapted filter output by adaptively filtering the corrected complex valued symbol signal.

20. A communication system, comprising:

a digital communications transmitter;

a communications medium; and

a digital communications receiver, comprising:

a input receiving a modulated analog signal containing digital information;

an analog to digital converter connected for producing a complex-valued digital signal from the modulated analog signal;

a demodulator connected for producing a demodulated complex valued digital signal from the complex valued digital signal;

a digital equalizer connected for receiving the demodulated complex valued digital signal, comprising:

a first filter operable receiving the demodulated complex valued digital signal;

a second filter connected to the first filter and operable for reducing the amount of noise and inter symbol interference in the demodulated complex valued digital signal; and

a symbol-to bit converter connected to the second filter.

21. The communication receiver according to claim 1 wherein the receiver is used with a digital subscriber loop of a telephone network.

22. The communication receiver according to claim 1 wherein the receiver is used with a coaxial cable television infrastructure.

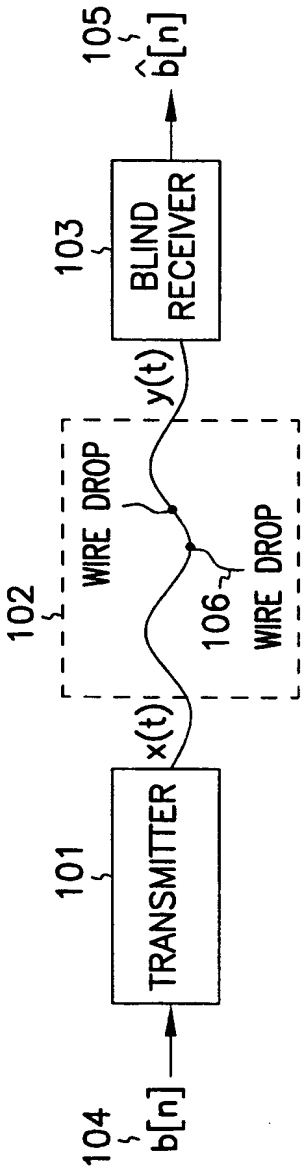
104
b[n]
101
TRANSMITTER
x(t)
102
WIRE DROP
106
WIRE DROP
y(t)
103
BLIND RECEIVER
105
$\hat{b}[n]$

FIG. 1

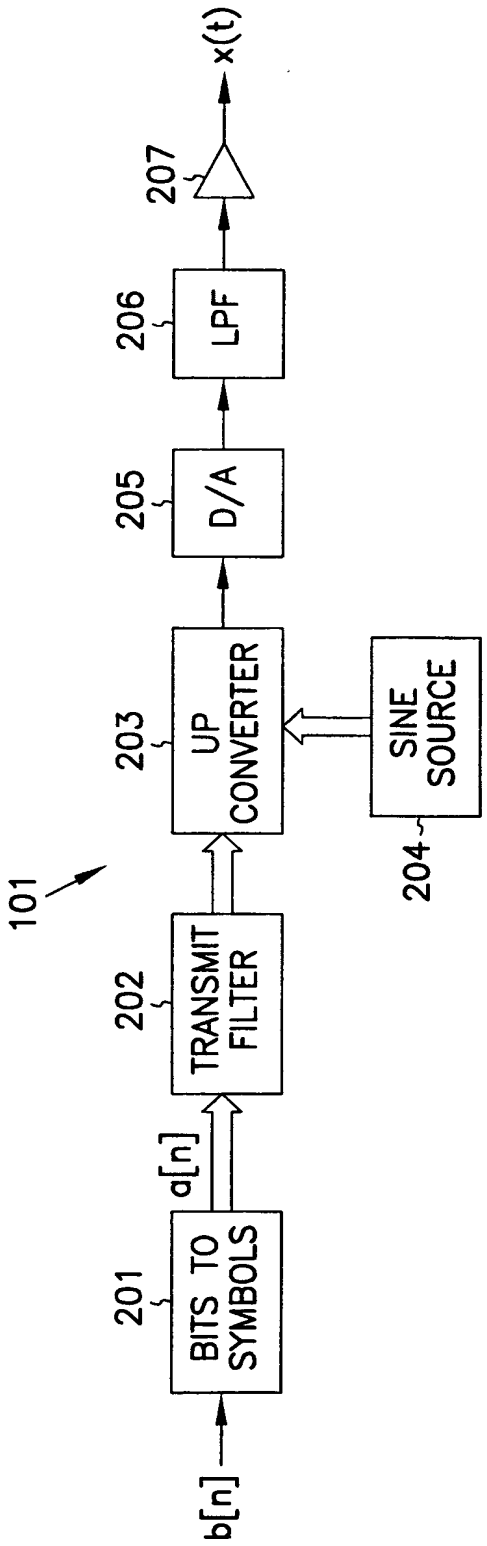
b[n]
201
BITS TO SYMBOLS
a[n]
202
TRANSMIT FILTER
101
203
UP CONVERTER
204
SINE SOURCE
205
D/A
206
LPF
207
x(t)

FIG. 2

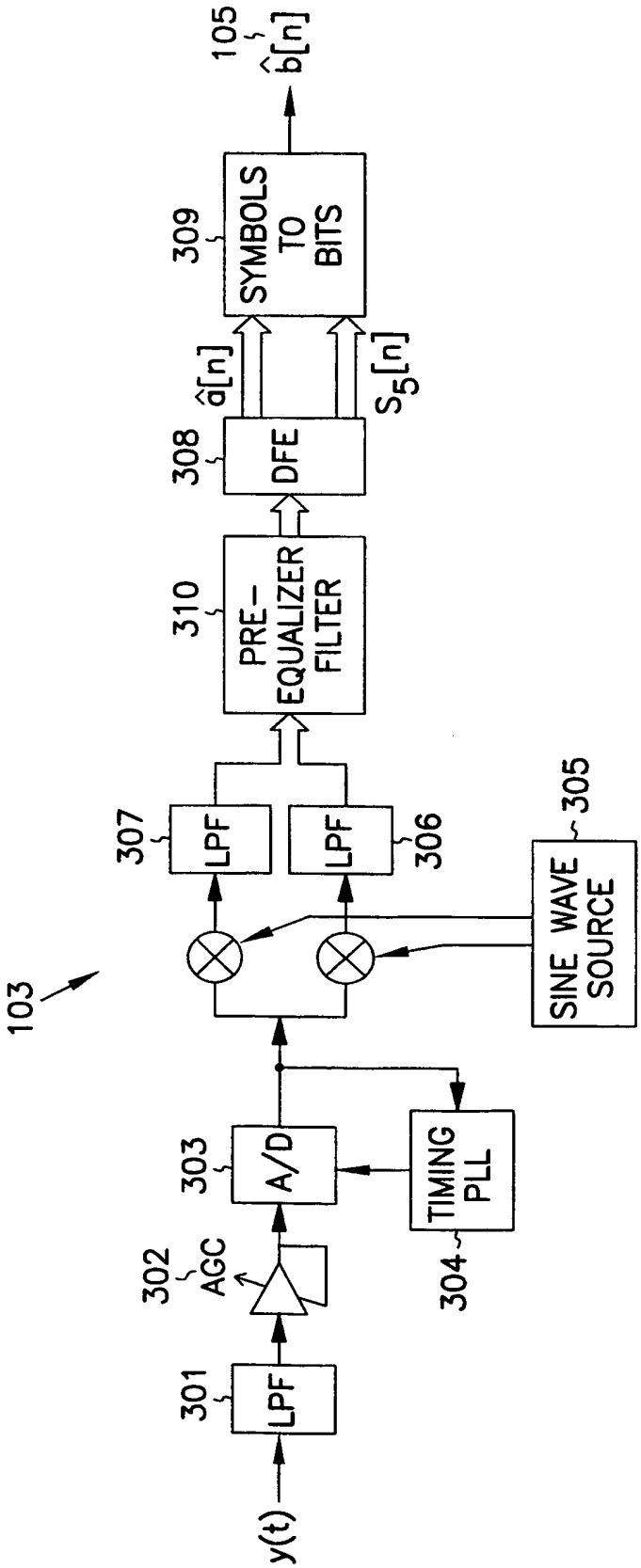
y(t)
LPF
301
AGC
302
A/D
303
TIMING PLL
304
SINE WAVE SOURCE
305
LPF
306
LPF
307
103
PRE-EQUALIZER FILTER
310
DFE
308
SYMBOLS TO BITS
309
105
$\hat{b}[n]$
$\hat{a}[n]$
$S_5[n]$

FIG. 3

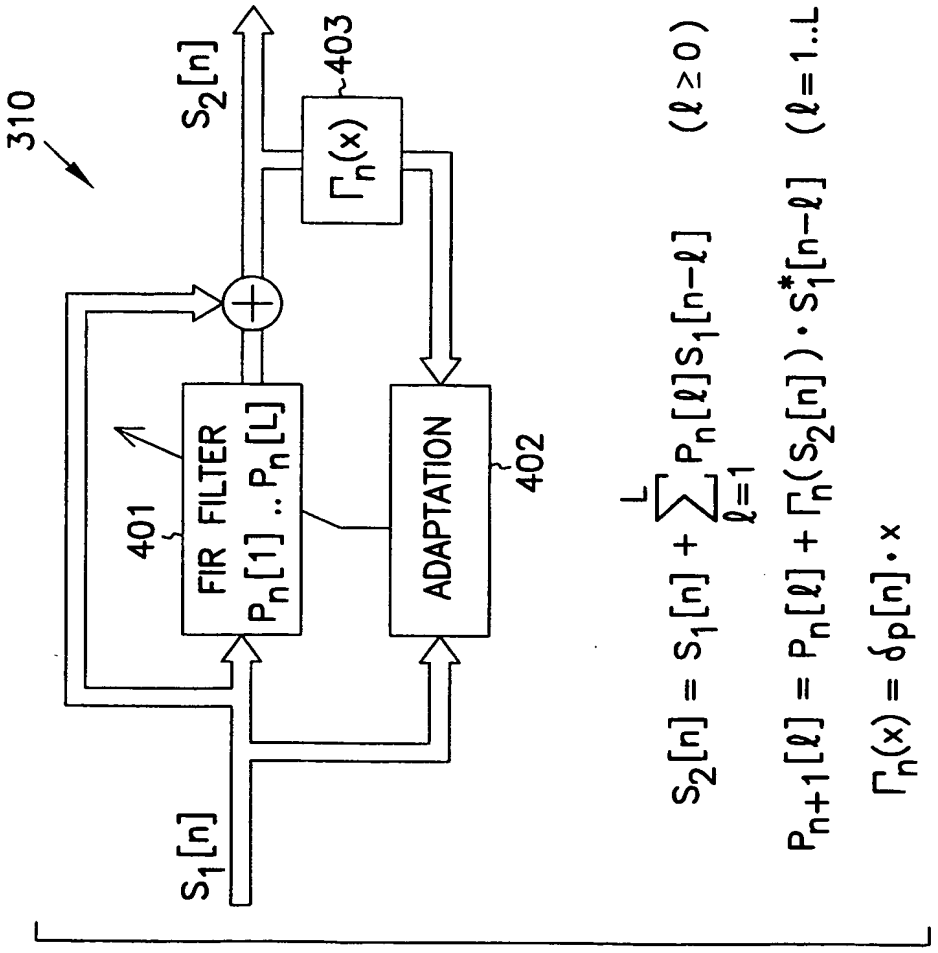
310
$S_2[n]$
403
$\Gamma_n(x)$
401
FIR FILTER
$P_n[1] .. P_n[L]$
ADAPTATION
402
$S_1[n]$
$S_2[n] = S_1[n] + \sum_{l=1}^{L} P_n[l] S_1[n-l] \quad (l \geq 0)$
$P_{n+1}[l] = P_n[l] + \Gamma_n(S_2[n]) \cdot S_1^*[n-l] \quad (l = 1..L)$
$\Gamma_n(x) = \delta p[n] \cdot x$

FIG. 4

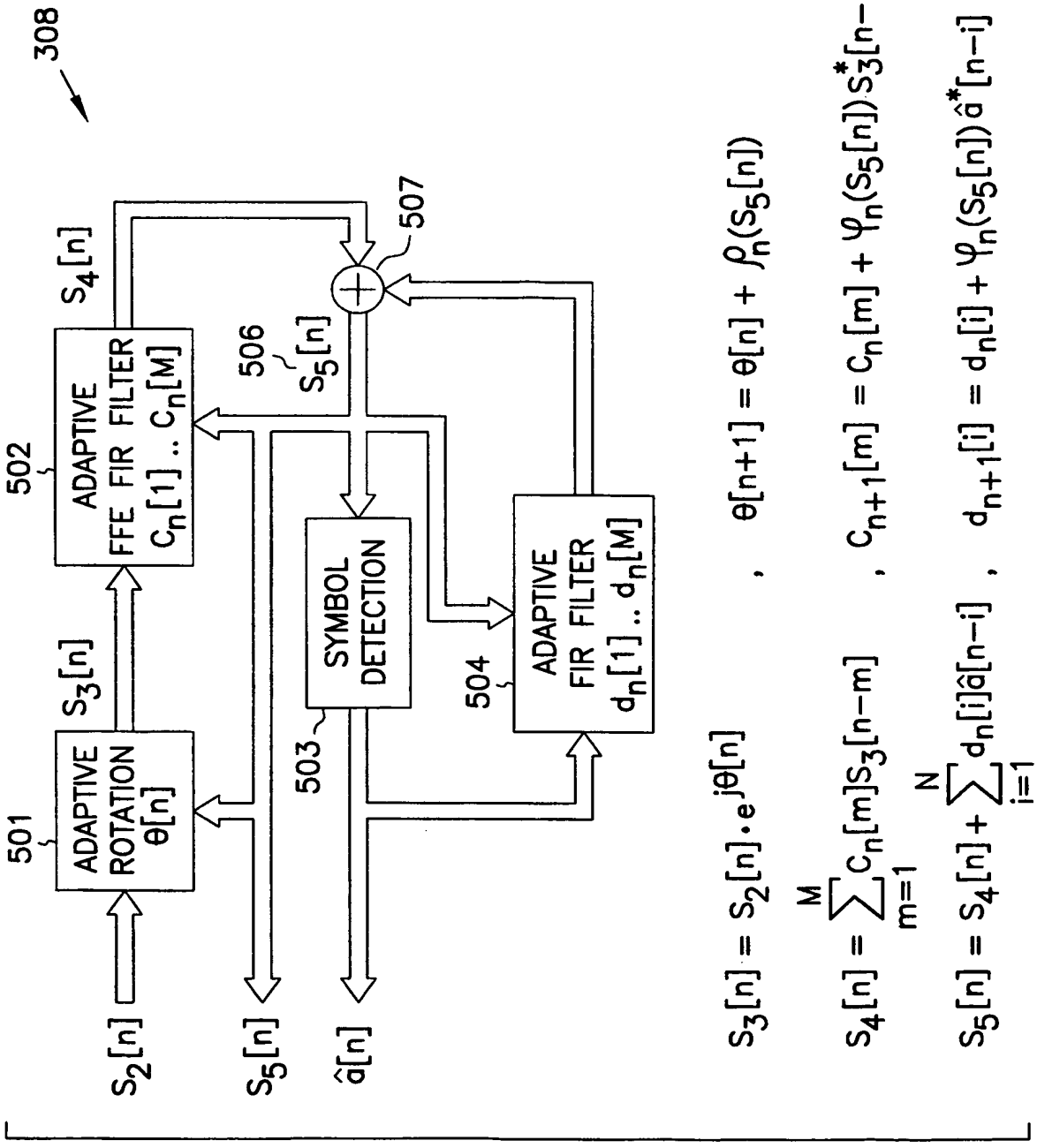
308
ADAPTIVE ROTATION θ[n]
501
ADAPTIVE FFE FIR FILTER $C_n[1] .. C_n[M]$
502
SYMBOL DETECTION
503
ADAPTIVE FIR FILTER $d_n[1] .. d_n[M]$
504
$S_2[n]$
$S_3[n]$
$S_4[n]$
$S_5[n]$
506
507
$\hat{a}[n]$
$S_3[n] = S_2[n] \cdot e^{j\theta[n]}$, $\theta[n+1] = \theta[n] + \rho_n(S_5[n])$
$S_4[n] = \sum_{m=1}^{M} C_n[m] S_3[n-m]$, $C_{n+1}[m] = C_n[m] + \varphi_n(S_5[n]) S_3^*[n-m]$
$(M \geq 1,\ N \geq 0)$
$S_5[n] = S_4[n] + \sum_{i=1}^{N} d_n[i] \hat{a}[n-i]$, $d_{n+1}[i] = d_n[i] + \varphi_n(S_5[n]) \hat{a}^*[n-i]$

FIG. 5

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WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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H04L 25/03

A3

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(30) Priority Data:
60/022,195 19 July 1996 (19.07.96) US

(71) Applicant *(for all designated States except US)*: LIBIT SIGNAL PROCESSING LIMITED [IL/IL]; P.O. Box 12670, 46766 Herzelia (IL).

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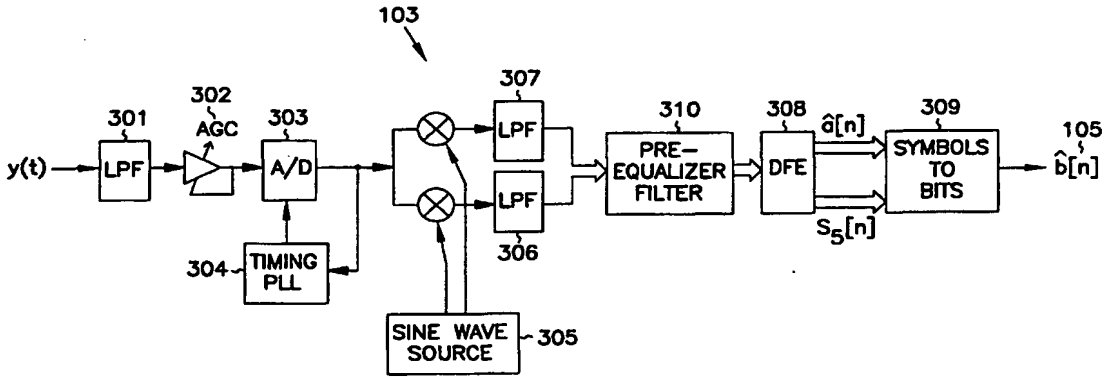
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(88) Date of publication of the international search report:
26 February 1998 (26.02.98)

(54) Title: BLIND DFE AND PHASE CORRECTION



(57) Abstract

The digital communications receiver receives an analog signal, modulated with digital information. The receiver converts the analogue signal to a digital signal, and demodulates the digital signal to recover the complex valued components of the transmitted digital signal. The complex valued components are low pass filtered and passed through an adaptive pre-equalizer filter, to reduce eigen value spread. The filtered complex valued signal is then subject to a decision feedback equalisation, which operates using a series of adaptive filters additionally to remove artifacts of inter-symbol interference. The resulting filtered and equalized complex valued signal is the converted to a digital signal to recover the digital information.

INTERNATIONAL SEARCH REPORT

Intern al Application No
PCT/IB 97/00903

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04L25/03

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	HATZINAKOS: "Blind equalization using decision feedback prediction and tricepstrum principles" SIGNAL PROCESSING, vol. 36, no. 3, April 1994, AMSTERDAM NL, pages 261-276, XP000435667 see abstract; figures 2,3 see page 262, left-hand column, paragraph 1 see page 263, left-hand column, paragraph 3 ---	1,20
X	US 5 297 166 A (BATRUNI) 22 March 1994 see figures 1,3 --- -/--	1,20

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 October 1997	15. 01. 98

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	SCRIVEN P.

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Interna al Application No
PCT/IB 97/00903

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	EP 0 729 254 A (ALCATEL) 28 August 1996 see abstract; figures 1,3 see page 3, line 27 - line 29 see page 6, line 16 - line 18	1,2,20
A	WO 95 09493 A (MOTOROLA) 6 April 1995 see abstract; figure 5 see page 3, line 5 - line 23 see page 14, line 1 - line 10	1,2,20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 97/00903

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see continuation sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1,2,20

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

1. claims 1,2,20: equalisation with a pre-equaliser to reduce eigenvalue spread
2. claim 3: blind equalisation
3. claim 4: blind compensation for phase offsets
4. claim 5: blind decision feedback equalisation
5. claim 6: equalisation with an FIR filter as a pre-equaliser
6. claims 7-13: adaptation rules
7. claim 14: decision feedback equaliser with compensation for phase offsets
8. claim 15: receiver for various modulation formats
9. claims 16-19: decision feedback equalisation with a pre-equaliser, phase rotator
10. claim 21: equalisation in a digital subscriber loop of a telephone network
11. claim 22: equalisation in a coaxial cable television network

INTERNATIONAL SEARCH REPORT

Information on patent family members

Interna[illegible]al Application No
PCT/IB 97/00903

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5297166 A	22-03-94	NONE	
EP 0729254 A	28-08-96	IT MI950355 A	26-08-96
		CA 2170195 A	25-08-96
		CN 1138251 A	18-12-96
		JP 8321795 A	03-12-96
		NO 960575 A	26-08-96
WO 9509493 A	06-04-95	US 5414699 A	09-05-95
		AU 1664195 A	18-04-95
		BR 9407664 A	28-01-97
		CN 1132010 A	25-09-96
		EP 0721713 A	17-07-96
		JP 9503362 T	31-03-97

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (PCT/IPEA/416)
299.004W01		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/IB97/00903	18/07/1997	19/07/1996
International Patent Classification (IPC) or national classification and IPC		
H04L25/03		
Applicant		
LIBIT SIGNAL PROCESSING LIMITED et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

I	☒	Basis of the report
II	☐	Priority
III	☒	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	☐	Lack of unity of invention
V	☒	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	☒	Certain documents cited
VII	☒	Certain defects in the international application
VIII	☒	Certain observations on the international application

Date of submission of the demand	Date of completion of this report
18/02/1998	13. 10. 98
Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. (+49-89) 2399-0, Tx: 523656 epmu d Fax: (+49-89) 2399-4465	Schweitzer, J-C Telephone No. (+49-89) 2399-8963

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/IB97/00903

I. Basis of the report

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

Description, pages:

1-8 as originally filed

Claims, No.:

1-22 as originally filed

Drawings, sheets:

1/4-4/4 as originally filed

2. The amendments have resulted in the cancellation of:

☐ the description, pages:
☐ the claims, Nos.:
☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been examined in respect of:

☐ the entire international application.

☒ claims Nos. 3 - 19, 21, 22.

because:

☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (*specify*):

☐ the description, claims or drawings (*indicate particular elements below*) or said claims Nos. are so unclear that no meaningful opinion could be formed (*specify*):

☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

☒ no international search report has been established for the said claims Nos. 3 - 19, 21, 22.

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1, 2, 20
	No:	Claims	
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1, 2, 20
Industrial applicability (IA)	Yes:	Claims	1, 2, 20
	No:	Claims	

2. Citations and explanations

see separate sheet

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

and / or

2. Non-written disclosures (Rule 70.9)

see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Concerning section V.2 (reasoned statement under Article 35 (2) PCT)

Claim 1 defines a digital communication receiver for modulated analog signals containing digital information comprising, in a typical manner, an input for receiving said signals, a front end performing various functions such as A/D conversion, demodulation and timing control, a digital equalizer and a symbol-to-bit converter. Such a receiver structure is arguably well-known in the art, in particular in the field of QAM receivers.

According to the present disclosure, the alleged invention lies in the provision of a particular (blind) digital equalizer, which is defined in claim 1 by comprising a first filter (which is not clearly defined by any limiting features, see also section VIII below) and a second filter operable for reducing the amount of noise and inter symbol interference (ISI) in the demodulated complex valued digital signal.

The cited article by **Hatzinakos [Signal Processing, April 1994],** hereinafter referred to as document **D1,** already discloses such a blind equalizing arrangement using a decision feedback equalizer (DFE) permitting to reduce the amount of (white Gaussian) noise and ISI in a demodulated, baseband digital signal, see p. 262, left-hand column and p. 262, second full paragraph.

Similarly, the cited **D2 = US-A-5 297 166 [Batruni]** describes such a blind mode DFE, which is used in combination with a pre-equalizer filter, cf. Fig.1 and col.1, line 34 to col.2, line 32.

To a skilled person, therefore, starting from a typical (QAM) receiver and wishing to solve the general problem mentioned in the application, i.e. avoiding noise and ISI problems, it would be rather obvious to apply the equalization techniques known from **D1/D2,** with corresponding effect, to said conventional receiving arrangement and hence to arrive, without the need to exercise any inventive activity, at the subject-matter of claim 1, such an application being regarded as falling within the normal technical competence of a skilled person who applies the knowledge and common sense expected of such, especially as the advantages thus achieved can be readily contemplated in advance. Consequently, the subject-matter of claim 1 in its present, broad formulation lacks an inventive step and hence does not meet the requirements of Article 33(3) PCT.

Independent claim 20 relates to a communications system comprising a digital transmitter, a communications medium and a digital receiver as set out in claim 1; hence the arguments concerning lack of inventive step set out above apply equally to said system claim 20.

Dependent claim 2 adds nothing of inventive significance to claim 1, as the additional feature introduced by said claim, namely the use of a (pre-) filter for reducing the Eigenvalue spread of an input spectrum of a demodulated signal, is generally known in the art and e.g. to be found in the additionally cited **D3= WO-A-95/09493 [Motorola]**, cf. p. 14, lines 1 to 19. Thus, claim 2 can also not be considered to offer a basis for an inventive main claim.

Concerning section VI.1 (certain published documents)

The priority document pertaining to the present application was not available at the time of establishing this first written opinion. Hence, it is based on the assumption that all claims enjoy priority rights from the filing date of the priority document. If it later turns out that this is not correct, the document **EP-A-0 729 254** cited in the international search report (published on 28.08.96) could become relevant to assess whether the claims satisfy the criteria set forth in Article 33(1) PCT.

Concerning section VII (form and contents).

In order to meet the requirements of Rule 5.1.(a),(ii) PCT, the relevant prior art, i.e. at least the documents **D1** and **D2** noted above, should have been acknowledged by reference and briefly discussed in the introductory part of the description.

The claims do not include reference signs in parentheses where features shown in the drawings are referred to, Rule 6.2.(b) PCT.

Concerning section VIII (clarity).

Claim 1 lacks clarity, contrary to Article 6 PCT, as it recites a "first filter" which is merely defined as being "operable receiving the demodulated complex valued digital signal". Thus, neither the nature nor the actual function of said first filter, which actually appears to correspond to the "pre-equalizer filter" described in relation with Fig.4, is clearly and sufficiently defined.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (PCT/IPEA/416)
299.004W01		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/IB97/00903	18/07/1997	19/07/1996
International Patent Classification (IPC) or national classification and IPC		
H04L25/03		
Applicant		
LIBIT SIGNAL PROCESSING LIMITED et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

I	☒	Basis of the report
II	☐	Priority
III	☒	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	☐	Lack of unity of invention
V	☒	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	☒	Certain documents cited
VII	☒	Certain defects in the international application
VIII	☒	Certain observations on the international application

Date of submission of the demand	Date of completion of this report
18/02/1998	13.10.98
Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. (+49-89) 2399-0, Tx: 523656 epmu d Fax: (+49-89) 2399-4465	Schweitzer, J-C Telephone No. (+49-89) 2399-8963

Form PCT/IPEA/409 (Cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/IB97/00903

I. Basis of the report

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

Description, pages:

1-8 as originally filed

Claims, No.:

1-22 as originally filed

Drawings, sheets:

1/4-4/4 as originally filed

2. The amendments have resulted in the cancellation of:

☐ the description, pages:
☐ the claims, Nos.:
☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been examined in respect of:

☐ the entire international application.

☒ claims Nos. 3 - 19, 21, 22.

because:

☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (*specify*):

☐ the description, claims or drawings (*indicate particular elements below*) or said claims Nos. are so unclear that no meaningful opinion could be formed (*specify*):

☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

☒ no international search report has been established for the said claims Nos. 3 - 19, 21, 22.

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1, 2, 20
	No:	Claims	
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1, 2, 20
Industrial applicability (IA)	Yes:	Claims	1, 2, 20
	No:	Claims	

2. Citations and explanations

see separate sheet

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

and / or

2. Non-written disclosures (Rule 70.9)

see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Concerning section V.2 (reasoned statement under Article 35 (2) PCT)

Claim 1 defines a digital communication receiver for modulated analog signals containing digital information comprising, in a typical manner, an input for receiving said signals, a front end performing various functions such as A/D conversion, demodulation and timing control, a digital equalizer and a symbol-to-bit converter. Such a receiver structure is arguably well-known in the art, in particular in the field of QAM receivers.

According to the present disclosure, the alleged invention lies in the provision of a particular (blind) digital equalizer, which is defined in claim 1 by comprising a first filter (which is not clearly defined by any limiting features, see also section VIII below) and a second filter operable for reducing the amount of noise and inter symbol interference (ISI) in the demodulated complex valued digital signal.

The cited article by **Hatzinakos [Signal Processing, April 1994]**, hereinafter referred to as document **D1**, already discloses such a blind equalizing arrangement using a decision feedback equalizer (DFE) permitting to reduce the amount of (white Gaussian) noise and ISI in a demodulated, baseband digital signal, see p. 262, left-hand column and p. 262, second full paragraph.

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